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REVIEW OF GEODUCK HATCHERY PROTOCOLS CURRENTLY IN PLACE FOR THE STRAIT OF GEORGIA AND EVALUATION OF POTENTIAL APPLICATION TO OTHER COASTAL AREAS IN BRITISH COLUMBIA

Context

Aquaculture of the Pacific Geoduck (*Panopea generosa*) (herein referred to as "Geoduck") has been underway in the Pacific Northwest since the early 1990s when Washington State began experimenting with Geoduck hatchery and seed grow-out techniques. In 1996, a federal/provincial pilot program for Geoduck aquaculture research and development was approved in British Columbia (BC) with the establishment of five subtidal aquaculture sites.

Potential impacts of subtidal Geoduck aquaculture on conservation of wild Geoduck populations and the harvestable Total Allowable Catch in BC were reviewed by Hand and Marcus (2004). Development of Geoduck aquaculture in BC was then restricted to the Strait of Georgia until more could be learned about Geoduck genetics and diseases and to allow the development of the regulatory framework. As part of a phased expansion in 2006, 11 new subtidal sites were offered for Geoduck aquaculture licence application in the Strait of Georgia.

Genetic and disease monitoring was identified by Hand and Marcus (2004) as an important component of understanding and mitigating potential impacts of Geoduck aquaculture on wild Geoduck populations. With the recognition that genetic mixing and disease transfer may occur between wild and cultured Geoduck, an internal Fisheries and Oceans Canada (DFO) working group provided advice on interim protocols for brood stock collection, genetic sampling and disease reporting. DFO had no regulatory authority at that time to oversee the implementation of the recommended protocols as aquaculture regulatory authority rested with the BC Provincial government. In December 2010, DFO assumed control of aquaculture regulatory authority and licensing, following the BC Supreme Court directed transfer of administration and regulatory control of aquaculture in BC to the federal government.

With regulatory authority for Geoduck aquaculture now being a DFO responsibility and with interest in expanding Geoduck aquaculture beyond the Strait of Georgia, the Aquaculture Management Division has requested science advice on the following questions:

1. Do operational standards in current Geoduck hatchery protocols ensure that risks and concerns around genetic mixing and disease transfer issues are adequately addressed and mitigated?
2. Are the protocols relevant to, and mitigate risks of, an expanded aquaculture fishery beyond the Strait of Georgia?
3. Do existing protocols need to be amended? If so, provide recommendations along with rationales for such changes.
4. Under what scenarios would the collection of baseline samples, prior to out-planting of hatchery-reared stocks, be required and how would such a program be defined?

This report builds on past recommendations and makes additional recommendations to improve Geoduck brood stock collection and hatchery procedures. Genetic and disease-transfer concerns are described and measures to mitigate risks are proposed. An overview of practices used in other jurisdictions (Alaska and Washington State) is provided. Some of the current draft protocols address concerns around genetics and disease transfer. However, additional measures are recommended in order to mitigate the risks associated with Geoduck aquaculture.

This Science Response Report results from the Science Response Process of May 2013 on the Review of Geoduck Hatchery Protocols Currently in Place for the Strait of Georgia and Evaluation of Potential Application to Other Coastal Areas in British Columbia.

Background

There are currently 57 aquaculture sites licensed to rear Geoducks in BC in the Strait of Georgia, 16 sites are licensed for subtidal culture, 25 for intertidal or mixed zone culture and 9 for hatcheries. Outside the Strait of Georgia, there are 2 licensed hatcheries (one in Bamfield on the West Coast of Vancouver Island (WCVI) and one in Prince Rupert), one experimental nursery-only site in the North and 4 licensed and inactive grow-out sites on the WCVI. DFO has received 26 licence applications for new Geoduck aquaculture sites or amendments to existing sites, not only in the Strait of Georgia but in other parts of the BC coast. New Geoduck hatcheries have been proposed in Sooke (WCVI) and Haida Gwaii. There is considerable interest from aquaculturists to expand BC Geoduck aquaculture outside of the Strait of Georgia.

Documents Reviewed

There are currently no publications describing Geoduck brood stock collection and hatchery procedures. Three documents were drafted in 2005 and 2006 by a team of DFO experts to examine issues related to Geoduck disease and genetic fitness, and to make recommendations to resource managers, industry and the Province on concerns, risks and potential solutions.

1. Genetic protocol and infectious disease considerations for culturing Geoduck for aquaculture or wild stock enhancement purposes
2. Interim Geoduck brood stock, seed holding, and transfer guidelines
3. Geoduck sample collection field guidelines for baseline genetic and disease monitoring

These documents were developed for different purposes and cover a range of issues pertinent to this current review. It is important to note that none of these documents were published, but they were used to develop management measures. There are, therefore, no published "current Geoduck brood stock collection and hatchery protocols".

The draft documents recommend measures regarding hatchery operations; including minimum Geoduck brood stock number, brood stock renewal, brood stock and seed transfer regulations, *etc.* Some measures were followed, while others were not, in part because DFO did not have the legal authority to enforce many of the recommended measures until December 2010.

Measures recommended in the three draft documents

Recommendations from the draft documents pertaining to Geoduck brood stock collection and hatchery protocols are summarized in Appendix 1. Some of the recommendations were inconsistent or contradictory, and not all were implemented at the time. Recommendations that were of a regulatory or management nature were not included in Appendix 1, as the current report focuses solely on Science related concerns.

The term "Zone" is used throughout this report to refer to Shellfish Transfer Zones as defined by the Introductions and Transfers Committee (Appendix 2).

General concerns

General concerns expressed in the draft documents relate to lack of understanding of Geoduck population genetics and potential impacts to wild stocks. Recommendations included limiting Geoduck enhancement/culture activities to a single Zone and monitoring for genetic shifts and impacts. The Strait of Georgia was the recommended Zone for initial development, with several Geoduck culture projects already underway in the mid-2000s and expansion planned. Collection of genetic samples for new sites and further sampling to determine whether there is genetic separation between northern and southern populations in the Strait of Georgia were recommended.

In addition, when there were occurrences of Geoducks with abnormalities such as warts, scars or dark discoloration, it was recommended that samples be collected and submitted to the Pacific Biological Station (PBS) Shellfish Health unit for analysis.

Brood stock

The draft documents recommended that only brood stock local to a Zone be used to produce seed for out-planting to that Zone, and that seed or juveniles only be transferred to the Zone of brood stock origin. A minimum collection of 100 animals for brood stock was recommended; however, recommendations for a minimum number of animals to spawn at one time in the hatchery were not implemented. Geoduck brood stock collection permits between 2006 and 2012 ranged from 100 to 250 individuals each. Other recommendations included an annual refresh rate for brood stock and directives for collecting brood stock from wild populations rather than from aquaculture tenures.

Collection of genetic samples from brood stock was recommended. Genetic samples were taken from many brood stock collections of wild Geoducks off tenure, but genetic analysis was not conducted. Additional health and genetic sampling was recommended for Geoduck brood stock or seed being transferred to or from out-of-Zone hatcheries. The first transfer of Geoducks to an out-of-Zone hatchery occurred in 2012, with the hatchery running under approved isolation and quarantine conditions.

Progeny

Prior to out-planting hatchery-reared seed, it was recommended to establish baseline genetic sample collections (100 animals) of the neighbouring populations most likely to be impacted. It was acknowledged that these genetic samples might never be analyzed, but if specific concerns arose, the data would be useful if the samples could be analyzed successfully.

Shellfish Transfer Zones

The draft documents recommended the use of the five Shellfish Transfer Zones (Appendix 2), developed by the Introductions and Transfers Committee (ITC), that were in operation at the time and have since been described in the Federal Shellfish Aquaculture Licence and Conditions of licence.

Seed or juveniles transferred from a hatchery facility to a grow-out location within the same Zone as the hatchery and brood stock origin did not require additional health and genetic testing.

When Geoduck brood stock were collected to hold in a hatchery outside of the original collection Zone with the intent of returning seed to the original Zone, collection of tissue samples from 100% of brood stock for genetic analysis was recommended. Complete separation of stocks

from any local stocks was specified, if the brood stock origin and seed out-planting destination were outside the Zone of the hatchery location. Isolation and quarantine requirements for hatcheries were prescribed, as well as genetic parental testing of seed by lot and health checks to the satisfaction of the ITC prior to return of seed to the original Zone of brood stock harvest.

Of the recommendations listed above, some were implemented, while others were not, for a variety of reasons. Many of the recommendations are still relevant and should be carried forward. However, some recommendations require review, some are not relevant and some additional recommendations are required to mitigate risks associated with Geoduck aquaculture.

Analysis and Response

Genetic Concerns

Genetic concerns associated with Geoduck aquaculture in BC focus on: (1) genetic alteration of cultured populations due to hatchery spawning and rearing practices and (2) impacts of out-planted Geoducks on the genetic characteristics of wild populations, through interactions of out-planted Geoducks and their offspring with wild populations. With the culture of a native species, genetic risks centre on potential loss of genetic variation, which in nature serves to buffer a population against natural selective forces (Straus et al. 2008).

Hand and Marcus (2004) highlighted that genetic concerns exist around out-planting of hatchery-reared Geoducks into the wild. More specifically, the genetic concerns are:

1. Are the brood stock used for cultured animal production genetically distinct from the local wild population?
2. Are Geoduck seed produced in hatchery genetically distinct from:
   a) parental brood stock (altered by reduced genetic variability or selection within the culture environment)?
   b) surrounding wild populations, from which the seed may or may not be derived?
3. What is the effective number of parents that contribute to produce seed in hatcheries?
4. What are the impacts of the reproduction of out-planted cultured Geoducks on the genetic structure and diversity of surrounding wild Geoduck populations?

Different genetic sampling programs would be required to answer these questions. One study was conducted to investigate the genetic structure of wild Geoduck stocks in BC (Miller et al. 2006), in which a complex population structure was identified among Geoduck samples from 14 sites in BC and two in Washington. BC sampling sites included West Coast Haida Gwaii, WCVI, Strait of Georgia and Queen Charlotte Sound. No samples were available from East Coast Haida Gwaii, the BC North Coast or BC Central Coast. Given demonstrated genetic differences, which may include adaptations to local environments, Miller et al. (2006) recommended that movement of Geoduck brood stock and seed should only be permitted within a given Zone, because introduction of animals from distant sources carries the risk that animals will be poorly adapted to the local environment. Collecting and analyzing more wild Geoduck genetic samples, especially from areas of the coast that have not been sampled to date, would help determine if the Zones are an appropriate scale of management, or if allowable distance between brood stock collection and seed out-plant should be smaller. As long as local animals are used in hatchery production, the concern for the cultured strain itself is primarily a loss of diversity, due to a small 'effective population size' as a result of low brood stock numbers or variable reproductive success among brood animals.

Between 2005 and 2012, 16 wild Geoduck brood stock DNA samples were collected and submitted to the Genetics Laboratory at PBS. Sample collection was not comprehensive and no tissue samples were collected from hatchery-reared juveniles. None of these samples have been analyzed. Most Geoduck brood stock that have been spawned to date were collected from wild populations and are expected to be genetically representative of the wild populations from which they were drawn.

A major genetic concern relates to whether the hatchery-produced seed differs genetically from the brood stock and/or wild population surrounding the out-planting area. This scenario could occur if the number of effective spawners in the hatchery is low, or if there are selective pressures in the hatchery. Although hatcheries typically attempt to provide a benign environment to ensure non-selective high survival, Geoduck larval and seed survival in BC hatcheries has had mixed success, and the possibility of altered selective forces within hatcheries cannot be excluded. Domestication (adaptive genetic alteration of organisms due to the hatchery environment) is expected to accumulate over time (generations of rearing) if cultured Geoducks were to be used for spawning each generation. The use of wild Geoducks as brood stock each generation precludes the development of highly divergent hatchery strains for use in aquaculture.

The first step in investigating whether seeded Geoducks might lead to impacts on the genetic composition of Geoducks in wild populations would be to determine if hatchery-produced Geoducks can be differentiated genetically from wild populations. Hatchery-produced shellfish have been found to be genetically distinct from their wild counterparts for many species, often due to reduced genetic variability and genetic drift (Straus et al. 2008). Genetic alteration of genes controlling adaptive traits cannot be directly monitored, but changes in non-coding microsatellite loci may provide information on loss of genetic diversity, inbreeding and potential for domestication (adaptive changes). There is strong indication that wild Geoduck populations have high levels of genetic variability that could be perturbed by gene flow from cultured genotypes (Straus et al. 2008). Since DNA samples of hatchery-produced Geoducks have not been collected, no data are available on the number of successful spawners in hatcheries or the genetic make-up of hatchery-produced seed. Development of a sampling and analysis plan for brood stock, cultured progeny and surrounding wild populations would be required to determine the magnitude of genetic interactions between wild and cultured Geoducks.

Geoducks reproduce through broadcast spawning and can mature as early as 2 years (Campbell and Ming 2003). The grow-out period for seeded Geoducks is estimated to be 7 to 10 years and it is, therefore, probable that seeded Geoducks will spawn prior to being harvested. Since a major factor affecting fertilization rate and reproductive success in marine broadcast spawners is the distance between spawning individuals, high planting-densities of the cultured population could lead to high reproductive output compared to the reproductive success in lower-density neighbouring wild populations. This could create a situation where most of the Geoduck larvae in an area originate from cultured Geoducks, rather than from wild Geoducks. Geoduck larval duration is up to 50 days in the laboratory (Goodwin et al. 1979) (possibly longer in the wild) allowing for potential large-scale dispersal of larvae away from the spawning source. Larval dispersal patterns are not currently understood and therefore the geographic extent of potential genetic impacts is unknown. Genetic effects will manifest only after the offspring of out-planted Geoducks settle to a wild bed and reproduce with the resident wild population (see Straus et al. 2008).

A sampling plan and genetic analysis would be required to determine the extent and magnitude of potential genetic impacts. Lacking that, an approach that ensures wide genetic diversity in out-planted Geoducks is recommended. Such an approach could include a minimum number of adults to use during hatchery spawnings, maintaining an equal sex ratio in the brood stock, and

implementing a high 'refresh' rate of brood stock animals collected only from wild populations (not cultured individuals). There could also be limits for aquaculture production relative to the size of nearby wild populations within regions. The single use of a large numbers of spawners during mass spawning events in hatcheries does not ensure that viable progeny are contributed from all prospective brood animals, but would at least ensure higher genetic variability in the progeny than if fewer spawners were used. Ryman and Stahl (1980) suggested that no less than 30 males and 30 females should be used for hatchery production of salmonids. Tave (1999) suggested that, when using brood stock for one generation only, the effective breeding number required to have a 95% probability of keeping alleles that have a 1% frequency is 150, while an effective breeding number of 30 is required to have a 95% probability of keeping alleles that have a 5% frequency. The potential for overall reduction in genetic variability in wild populations, and resulting loss of adaptability, stresses the importance of a robust breeding program and effective monitoring. Controlled breeding designs or other means of monitoring parental genetic contributions could be developed to determine optimal numbers for Geoducks.

Genetic bottlenecks are known to occur in hatcheries, especially during production of animals from wild parents. In many cases, bottlenecks will only be detected by genetic analysis. To reduce the impact of an undetected loss of genetic variation due to bottlenecks, complete brood stock refreshment annually should be conducted in each hatchery to prevent ongoing genetic diversity loss in the out-planted animals. Ongoing use of wild animals as hatchery brood stock could limit the amount of adaptive change taking place in the cultured setting and, therefore, reduce the impact of genetic exchange between wild and cultured Geoducks.

Because the risks of a cumulative loss of diversity and adaptive changes in the cultured strain that are detrimental to wild populations increase if cultured animals are used as brood stock, use of cultured Geoducks as brood stock is not recommended. Prevention of cumulative genetic divergence between cultured and wild individuals is considered to reduce concern associated with the impact of genetic exchange in the wild environment. With no use of cultured Geoducks as brood stock, the concerns regarding genetic bottlenecks and strong adaptive modification of cultured strains are reduced.

Concerns raised by Hand and Marcus (2004) regarding the potential genetic impacts of Geoduck aquaculture on wild populations remain, because no new data on genetics of Geoduck brood stock and hatchery-produced seed are available. In the absence of more comprehensive sampling of wild Geoduck populations in BC and ongoing genetic assessment of hatchery strains and cultured-wild genetic interactions, maintaining the current within-Zone restriction for brood collection and juvenile out-planting is recommended. In addition, development of hatchery guidelines for brood stock numbers, spawning design and refresh rates would provide additional safeguards against potential detrimental genetic interactions between wild and cultured animals. Finally, establishing separate regions for the wild fishery and aquaculture, or placing region-specific limits on aquaculture production, would also mitigate the risk of a loss in wild population viability and diversity.

Disease Concerns

Bower and Blackbourn (2003) compiled a detailed overview of Geoduck anatomy, histology, development, pathology, parasites and symbionts on hatchery-reared out-planted Geoducks collected from four locations in the Strait of Georgia, wild animals from 18 locations in the Strait of Georgia, WCVI and Central Coast of BC. No infectious diseases or pathogenic organisms were detected in this analysis. Other peer-reviewed research on diseases specific to Geoducks is lacking for cultured animals and completely absent for wild stocks (Straus et al. 2008).

Under the *Health of Animals Act*, the Canadian Food Inspection Agency (CFIA) is now the regulatory authority for all aquatic animal diseases. Geoducks are currently not listed under the

Health of Animals Act as a susceptible host species for any of the mollusc diseases regulated and are not a priority species for the CFIA at the current time. This could change if a listed disease were to be detected in BC Geoducks.

With regards to disease, allowing movement of seed / brood stock only within the Zone of brood stock origin reduces the risk of disease transfer associated with aquaculture activities. Using a smaller spatial scale for brood stock collection, hatchery location and out-plant location could further reduce risks of disease transfer.

Because of genetic and disease concerns highlighted above, transfer of Geoducks for aquaculture purposes is recommended to only occur within a Zone (Appendix 2), *i.e.*, hatchery-produced Geoduck seed should only be out-planted in the Zone of brood stock origin. Due to the lack of Geoduck disease and genetic data for large portions of the BC coast, further research is needed to determine if the Zones are an adequate scale of management.

An exception to the preceding recommendation to restrict the movement of Geoducks between Zones can be made for the case of hatchery production of Geoduck seed in a different Zone than that where the brood stock came from, if additional measures to mitigate the disease and genetic risks are implemented. If a hatchery desires to import brood stock from a different Zone, it is recommended that both the water influent into the hatchery and water effluent out of the hatchery be treated to eliminate exposure and risks to local waters. Water treatment is most commonly carried out through particle filtration and ultraviolet irradiation of in-coming water supply and chlorine disinfection of effluent water. Influent treatment ensures that no pathogens or parasites of concern present in the Zone where the hatchery is located are passed onto the seed produced in the hatchery. Effluent treatment ensures that pathogens, parasites, non-native species and reproductive components associated with imported brood stock are kept out of waters in the Zone where the hatchery is located. Nursery rearing of seed produced from out-of-Zone brood stock (in pearl nets, mid-water trays, flupsies, Bags-On-Bottom, *etc.*) should not be permitted in Zones other than the Zone of brood stock origin, as there is no way to control for pathogen exposure in nursery conditions. Seed produced in a hatchery located in a Zone different than the Zone of brood stock origin should only be out-planted in the Zone of brood stock origin.

Mitigation Measures for Geoduck Aquaculture in Other Jurisdictions

Geoduck aquaculture also occurs in Washington State and Alaska. Both jurisdictions have highlighted similar concerns regarding potential genetic and disease impacts of Geoduck aquaculture on wild populations (Brickey et al. 2012, Straus et al. 2008). Because of these concerns, a number of regulations were put in place in Washington State and Alaska to mitigate the risks.

Alaska

Concerns around impacts of Geoduck aquaculture on wild Geoduck populations and management regulations implemented in Alaska to mitigate these risks were discussed by Brickey et al. (2012). It is against Alaskan State law to import Geoduck seed from outside the state. Brood stock is only used for one season. A minimum of 50 males and 50 females are required to be used each year. Only South-East Alaska Geoducks can be used as brood stock (Geoduck aquaculture in Alaska is limited to South-East Alaska).

Washington State

Similar concerns were identified in relation to Geoduck aquaculture in Washington State (Straus et al. 2008). If differences exist between wild and cultured Geoduck populations, minimizing gene flow from cultured to wild populations is vital to maintaining genetic integrity of wild

populations (Straus et al. 2008). Risk-reduction methods proposed by Straus et al. (2008) include collecting brood stock each year from the wild population with which their progeny will potentially interact and using a large number of wild brood stock. They suggested use of triploid animals in aquaculture as a means to prevent genetic interactions between wild and cultured Geoducks, but stated that the efficacy of triploidy in conferring sterility in Geoducks, and the permanence of triploidy, must be verified before using this technique.

Conclusions

A review of protocols, recommended in 2005 and 2006, to mitigate potential risks of Geoduck aquaculture was conducted and recommendations for amendments or additions to the existing protocols are provided. This assessment is based on the existing state of knowledge about the potential for disease transfer and genetic alteration of wild Geoduck populations in BC, and neighbouring jurisdictions. It should be noted that, although Geoduck aquaculture has been occurring in the Strait of Georgia since the early 1990's, previous advice for sampling and analysis pertaining to disease and genetic risks has not been fully implemented. Therefore, the assessment of the potential risks associated with Geoduck aquaculture remains largely unchanged from the previous assessment.

This review found that the existing Geoduck brood stock collection and hatchery protocols address some of the risks pertaining to genetic alteration and disease transfer; however, additional measures are recommended in order to mitigate the range of potential risks associated with Geoduck aquaculture. The following mitigation measures, taking into consideration existing information gaps, are recommended for Geoduck aquaculture activities within the Strait of Georgia and the rest of the BC coast, if Geoduck Aquaculture expansion proceeds beyond the Strait of Georgia:

1. Collect a minimum of 100 Geoducks for brood stock for each hatchery. Not all collected brood stock are expected to survive to spawning, and not all surviving Geoducks are expected to spawn; therefore, it is recommended that the number of Geoducks collected for brood stock be higher that the number required for spawning.
2. Use a minimum of 60 Geoducks when conducting hatchery spawnings (ideally 1:1 sex ratio) to mitigate risks of genetic diversity loss. Further genetic analysis of brood stock and associated seed to determine effective spawning population size is recommended to determine if this number is adequate.
3. Collect all brood stock, for each hatchery, from wild Geoduck populations and replace brood stock annually with fresh brood stock, in order to maximize genetic diversity of hatchery produced seed and reduce possible genetic impacts of out-planted Geoducks on wild populations.
4. Prohibit the use of hatchery-produced (cultured) Geoducks as brood stock due to the increased risks of genetic drift or selection in the hatchery production.
5. Restrict movement of Geoduck brood stock and seed to within Zones, as described by the Introductions and Transfer Committee (Appendix 2), or smaller spatial scale. Use only brood stock local to the Zone to produce seed for out-planting to that Zone. Restrict seed or juvenile transfers to the Zone of brood stock origin. Prohibit importing seed to a Zone other than the Zone of brood stock origin.
6. Establish quarantine protocols, for moving brood stock to and growing seed in out-of-Zone hatcheries; including standardized water treatment protocols for both influent and effluent water in and out of the hatchery to minimize risks of pathogen, parasite, and non-native species transfer between Zones.

7. Prohibit seed imports from Washington State, due to genetic differences observed between Strait of Georgia and Washington State Geoducks (Miller et al. 2006). Since the degree of genetic differentiation between BC and Alaska Geoduck populations is unknown, prohibit import of Geoduck seed from Alaska.
8. If a disease or mass mortality event occurs in a hatchery, collect and submit representative samples of live and moribund (weak) Geoducks to the Aquatic Animal Health laboratory at PBS for analysis. Dead and decomposing specimens are rarely of any value and should not be sent.

Many of the recommendations in this report are similar to recommendations and regulations to mitigate the risks associated with Geoduck aquaculture in neighboring jurisdictions (Washington State and Alaska).

The above recommendations are intended to mitigate risks of genetic alteration and disease transfer, taking into consideration existing information gaps. There are many unknowns regarding the genetic structure of wild Geoduck populations in BC and potential impacts of cultured Geoducks on wild Geoduck populations. Further scientific research is required, involving a program of tissue sampling and genetic analysis, to address the information gaps summarized in this paper, as well as to evaluate the efficacy of the mitigation measures recommended. Research recommendations include:

1. Further genetic and disease sampling of brood stock and seed to investigate the efficacy of proposed measures.
2. If Geoduck aquaculture expansion outside of the Strait of Georgia proceeds, genetic samples of Geoduck brood stock from areas of the BC coast where no samples have been collected to date (BC Central and North Coast and East Coast of Haida Gwaii) is recommended, to augment the knowledge of genetic structure of wild Geoduck populations and evaluate whether the existing Zones are of an appropriate scale for the management Geoduck aquaculture.
3. Comparing genetic samples from brood stock to their hatchery-reared seed is necessary to answer a number of questions regarding the number of effective spawners in hatcheries and if hatchery produced Geoduck seed can be differentiated genetically from the wild population.

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Sources of information

This Science Response Report results from the Science Special Response Process of May 2013 on the Review of Geoduck Hatchery Protocols Currently in Place for the Strait of Georgia and Evaluation of Potential Application to other Coastal Areas of British Columbia.

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Appendix 1 – Summary of interim recommendations from the three draft Geoduck brood stock collection and hatchery procedures documents reviewed

Only recommendations that are relevant to science issues are presented. Recommendations pertaining to management and regulatory regimes are outside the scope of this report.

Concerns

1. Until more is known about genetics and potential stock impacts, limit Geoduck enhancement/culture activity to a single Zone and monitor changes and impacts. The Strait of Georgia was the recommended Zone for initial development, with several Geoduck culture projects already underway in the mid-2000's, and an expansion planned.
2. Conduct further sampling and genetic testing within the Strait of Georgia with the aim of determining whether there is genetic separation between northern and southern populations.
3. Consider genetic sample collection as a component of the habitat/stock assessment process for new subtidal Geoduck sites.
4. At new Geoduck aquaculture sites, observers are asked to note the occurrence of "ugly ducks" – Geoducks with abnormalities, warts, fungus or dark discoloration. Where such individuals occur, collect up to 50 animals whole to provide as a biological sample from the site. If fewer than 50 are present in the harvest please collect all of them.

Brood Stock

5. Only brood stock local to the Zone may be used to produce seed for out-planting to that Zone. Seed or juveniles may only be transferred to the Zone of brood stock origin.
6. The recommended number of Geoduck brood stock to collect is 100.
7. Consider a refresh rate of a minimum of 20% per year, so that there is complete turnover of brood stock every five years.
8. Set a minimum number of spawners to be used at one time.
9. Consider guidelines around multiple spawnings with different brood stock in a season, and out-planting of mixtures of juveniles.
10. Collect brood stock away from the culture site, but in the same Zone, to reduce the likelihood that spawned generations are directly related.
11. Develop a genetic sampling protocol (n=100) for brood stock as a condition of the Scientific Licence for collection off tenure or as a condition of the Section 56 transplant permit on tenure.
12. Brood stock collection on an aquaculture tenure may be permitted upon submission of a wild stock harvest plan for review by DFO and MAFF.
13. Where Geoduck brood stock is collected under Scientific Licence or from a licensed aquaculture tenure and transferred under a Transfer Permit to a hatchery facility located within the same Zone as the capture, additional health or genetic testing is not required.

Progeny

14. Sample progeny (n=100) to establish the size of the founding population (number of parents) for each spawning.
15. Prior to out-planting of hatchery-reared seed, establish baseline data collections (n=100) of the neighbouring populations most likely to be impacted. These genetic samples may never be analyzed, but if specific concerns arise the data would be invaluable.

Shellfish Transfer Zones

16. The five Shellfish Transfer Zones will be used. Descriptions and map in Appendix 2.
17. Where seed or juveniles are transferred from a hatchery facility to an out-plant location within the same Zone as the hatchery and the brood stock capture, additional health and genetic testing is not required.
18. Where Geoduck brood stock is collected to hold in a hatchery outside of the original Zone with the intent of returning seed to the original Zone, tissue samples for genetic analysis are required to be collected from 100% of brood stock.
19. Tissue samples are to be collected by a DFO approved third party for genetic testing according to established DFO protocol. Genetic testing is to be carried out by the DFO laboratory or by a laboratory recognized by DFO. If the analysis is conducted in a non-DFO lab, two identical sets of tissue samples are to be collected, with one set going to the DFO lab for verification if required and one set going to the other lab for analysis.
20. The return of juveniles from out-of-Zone to Pacific Fishery waters will not be permitted until parental genetic testing is completed.
21. Complete separation of stocks from any local stocks must be maintained if the seed out-planting destination is outside the Zone of the hatchery location.
22. Incoming water to the hatchery must be treated with ultraviolet or equivalent to ensure that there is no contamination with disease pathogens or other organisms that may occur in local waters if the seed out-planting destination is outside the Zone of hatchery location.
23. Two additional steps are required for the Transplant Permit to out-plant the resulting seed stock to the original Zone.

Genetic parental testing

- For all out-of-Zone transfer requests, random genetic sampling of seed (100 seed/shipment) returning to the destination Zone are required to confirm parentage.
- Tissue samples from juveniles are to be collected by a qualified third party, for genetic testing according to established DFO protocol. If the genetic analysis is conducted in a non-DFO lab, two identical sets of tissue samples need to be collected, with one set going to the DFO lab for verification if required and one set going to the other lab for analysis.

Health status assessment

- Seed or juveniles transferred from a facility outside of the destination out-plant Zone must be held in isolation quarantine in a fish rearing facility until all testing is complete with both the parentage and the health status are confirmed and satisfactory to the ITC.

Appendix 2 – Shellfish Transfer Zones

Shellfish already in natural waters may be susceptible to diseases or parasites found in that area. Not all disease and parasites are common to all areas and so movements of shellfish from one Zone to another presents risk of disease transmission, especially if a disease or parasite known in one area is not found in a receiving area. Similarly, there may be risks of adverse ecological and genetic effects from moving shellfish from one Zone to another. These issues are addressed by delineating Zones based on our current knowledge of shellfish diseases and parasites in BC waters, and in consideration of ecological and genetic concerns. Figure 1 shows the five Zones established for shellfish introductions and transfers in BC For consistency and clarity, the Zones are defined by Fisheries and Oceans, Canada (DFO) Statistical Fisheries Management Areas* as in Table 1 and Figure 1.

Table 1: Description of Shellfish Transfer Zones.

Zone	Name	Description
1	Haida Gwaii	Contiguous waters surrounding Haida Gwaii within Areas 101, 102 and 142, and Areas 1 and 2.
2	North & Central Coast	Contiguous waters of the mainland coast within Areas 103 to 107, inclusive, Areas 109 and 110, and Areas 3 to 10, inclusive.
3	Queen Charlotte Strait	Contiguous waters of Queen Charlotte and northern Johnstone Straits within Areas 111, 11 and 12.
4	Georgia Strait	Contiguous waters of southern Johnstone, Georgia and Juan de Fuca Straits within Areas 13 to 19-4, inclusive, and Area 28 and 29.
5	West Coast Vancouver I.	Contiguous waters of the west coast of Vancouver Island within Areas 121 to 127, inclusive, and Areas 19-1, 19-2 & 19-3, to 27, inclusive.

*Charts of DFO Statistical Fisheries Management Areas are available online.

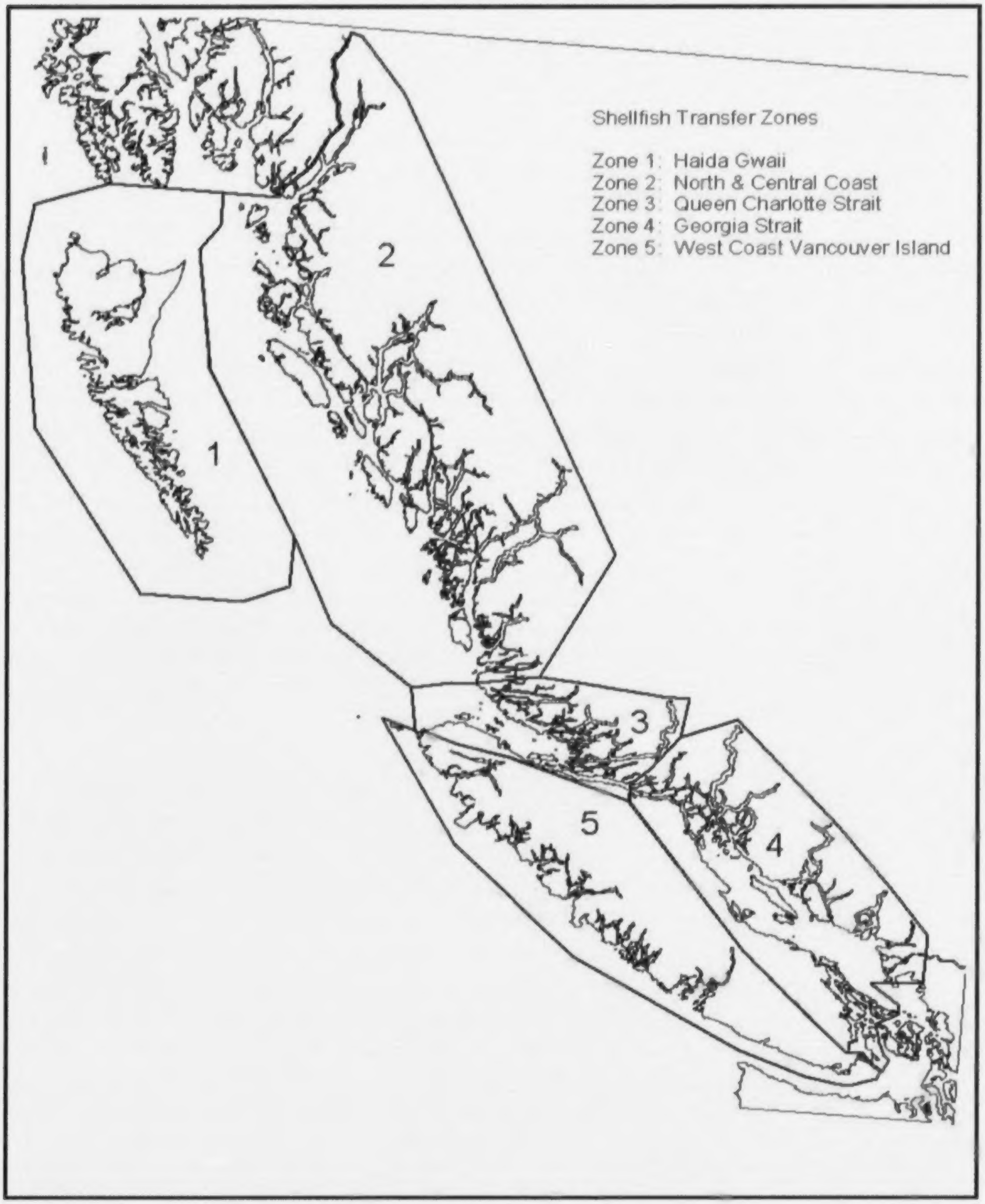

Figure 1: Shellfish Transfer Zones for Coastal British Columbia.

This Report is Available from the

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